Microbiological Air Quality Assessment of Seafood Plants as Impacted by Solid Waste

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ABSTRACT—Microbial populations (aerobic plate count, coliforms, and yeast and molds) in the air surrounding an oyster shell pile and a crab waste bin were periodically monitored to determine the relationship these populations had on the microbial populations observed inside the processing plants. Furthermore, environmental parameters such as temperature, relative humidity, wind speed, and wind direction were determined at the time of each sampling. Some relationships were observed between microbial populations in the air around the oyster shell pile and environmental factors to the airborne populations found inside the processing plant. No significant relationships were observed for the crab waste bins, this apparently due to frequent dumping and the use of lime. Although the contribution of airborne contamination from waste piles was shown to be comparatively small, the potential exists, and suggestions for mitigation are discussed.

Introduction

Crab and oyster processors often encounter periodic problems, especially during the summer months, with high bacteriological counts on their products. In the crab industry, excessive bacterial counts have often been attributed to such factors as crabs being spoiled prior to cooking, short cooking times, high proportion of egg bearing crabs, and temperature abuse of the product after cooking. However, in the oyster industry, the holding of shellstock at abuse temperatures prior to shucking has been shown to cause increases in total bacterial counts (Hood et al., 1983). Although any of these factors could potentially contribute to the problem, health department sanitarians have indicated that in some instances elevated bacterial counts on these products cannot reasonably be explained by any of the possibilities mentioned (Altman[1]).

Although airborne microbial contamination in food processing plants has been studied by other investigators (Kotula et al., 1978; Sunga et al., 1966; Heldman et al., 1966; and Sullivan, 1979), it has not been previously investigated in the seafood processing industry, particularly in reference to crab and oyster processing waste.

Crab and oyster processors have traditionally handled their waste by conveying it outside the plant and holding until disposal. Crab waste is usually removed once or twice a day depending on season; oyster shells, with proteinaceous material still adhering, may remain in shell piles for several days or perhaps weeks. Consequently, the possibility exists that these piles could serve as contaminant reservoirs if airborne particles carried bacterial contamination from the waste piles into the plant.

The objective of this study was to assess the influence of seafood waste disposal sites on the microbiological quality inside processing plants and the relationship certain environmental parameters may have to the process.

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[1]Altman, J. 1979. Virginia State Health Department, Bureau of Shellfish Sanitation, Norfolk, Ca. Personal commun.

Materials and Methods

Air Sampler

The air sampling device used in this project was a RCS Centrifugal Air Sampler[2] (Biotest Diagnostics Corp., Fairfield, N.J.). This device, either handheld or mounted on a tripod, has an impeller blade that pulls 20 L of air every 30 seconds into the impeller drum which contains an agar strip. The air, which enters the impeller drum concentrically and in a conical form, is set in rotation, and the particles contained in the air are impacted by centrifugal force onto the agar strip. The RCS sampler can be set to operate for 30 seconds, every 1, 2, 3, 4, or 8 minutes, depending on anticipated microbial loads.

Enumeration of Microorganisms

Microbial tests performed in this study were total aerobic count, coliform, and yeast and mold. These organisms were enumerated on trypticase soy agar (TSA), MacConkey's Agar (MA), and rose bengal agar (RBA), respectively. All agar strips were prepared and supplied by Biotest. TSA and MA strips were incubated at 35°C and enumerated at 48 hours, while RBA strips were also incubated at 35°C but enumerated at 120 hours.

Sampling at Shell Waste Piles

To accomplish the objective of this study, microbial air samples around the oyster shell waste pile (Fig. 1) and crab

[2]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

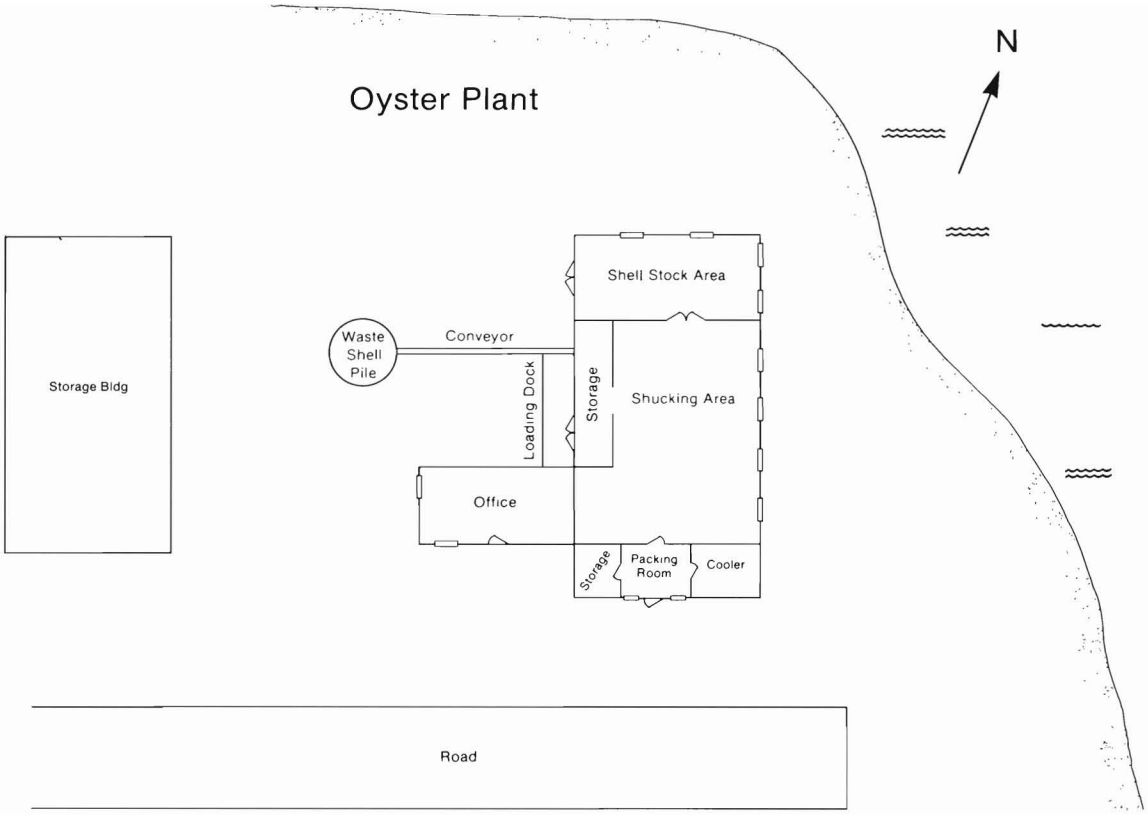
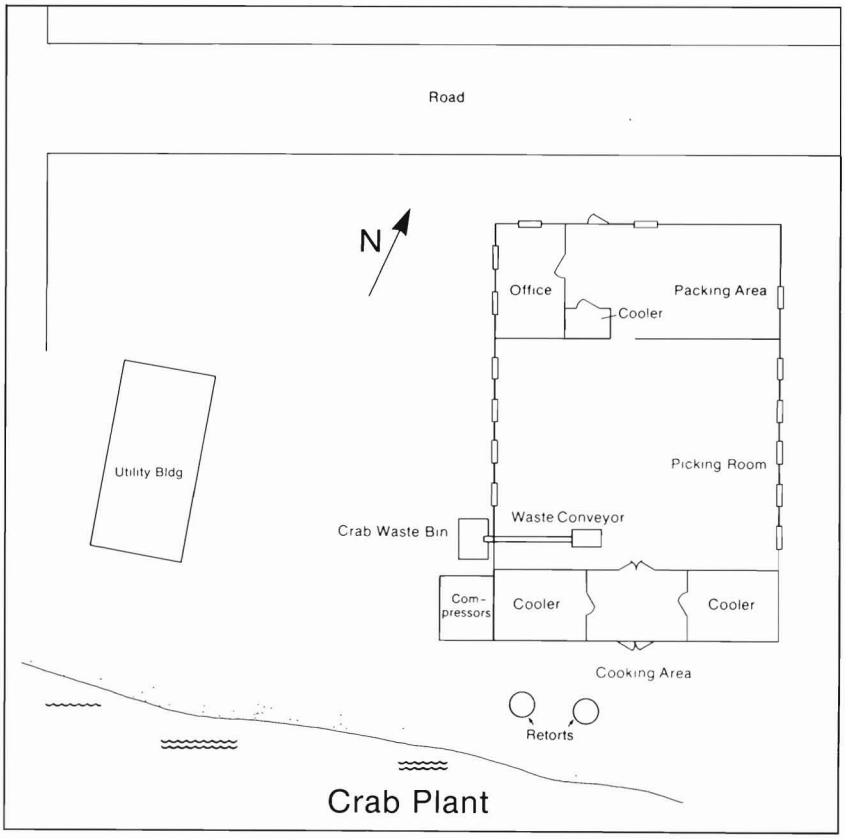


Figure 1.—Oyster plant layout and location of waste pile.

Figure 2.—Crab plant layout and location of waste bin.



waste bin (Fig. 2) were taken every 3-4 weeks for 1 year (1982-1983), except during the summer months (June, July, and August) when sampling was done every 1-2 weeks. Plants were located in the Tidewater region of Virginia.

Eight different sampling locations were selected around each waste site. Four sampling locations were selected at both 1 m and 8 m away from the waste piles. Once selected, sampling locations always remained the same. On each sampling day, duplicate samples were taken at each location with each sample taken 1 m above the ground. Additionally, duplicate air samples were also taken on each sampling day inside the plant. The inside location was selected such that it was nearest the point within the plant where contamination from the

piles would most likely gain entry, i.e., windows and doors. Figures 1 and 2 depict the location of the waste piles and general layout for the oyster plant and crab plant, respectively.

Other Measurements

In addition to monitoring the microbiological quality of the air, on each sampling day measurements were also taken of the temperature, relative humidity, wind velocity, and wind direction. Temperature and wind velocity were determined with a 100VT Air Velocity and Air Temperature Meter (Datametrics, Wilmington, Mass.). Relative humidity was measured with a sling psychrometer (Taylor Instrument Co., Rochester, N.Y.). Wind direction was determined by observing a small plastic ribbon attached to a tripod.

Table 1.—Meteorological conditions and number of organisms enumerated around oyster shell pile and inside oyster processing plant in 1983.

Month	RH[1]	Avg. wind speed[2]	WD[3]	Temp.[4]	Organisms/foot^3 of air					
					APC-I[5]	COL-I[6]	YM-I[7]	APC[8]	COL[8]	YM[8]
January	90	600	W	59	NT[9]	NT	NT	11.19	2.47	3.58
January	86	150	W	50	NT	NT	NT	11.37	4.15	4.02
February	94	130	E	51	4.25	NT	1.06	6.59	0.22	0.46
March	62	100	E	60	44.07	0.17	0.70	6.03	0.13	0.53
April	61	130	E	60	NT	NT	NT	30.62	0.26	5.41
May	78	30	E	65	16.10	1.94	6.90	8.31	0.19	4.77
June	77	100	W	85	233.64	0.17	1.77	47.23	2.63	7.39
June	92	125	SW	67	9.55	0.35	0.35	21.19	2.14	5.48
July	77	75	N	90	39.82	1.95	3.54	13.07	1.12	3.35
July	74	150	SE	89	15.22	1.06	5.42	16.69	1.28	5.54
July	63	50	E	94	NT	NT	NT	14.20	0.37	5.08
August	59	75	W	94	13.27	4.42	14.16	23.63	5.04	13.31
August	55	175	SW	85	310.10	3.00	15.04	44.80	4.21	12.74
September	71	75	E	84	NT	NT	NT	14.31	1.26	3.08
October	73	110	W	90	44.95	4.49	1.05	16.87	2.40	11.30
October	88	50	E	70	10.97	4.78	4.07	20.90	1.83	3.84
November	89	30	E	41	64.78	18.23	7.26	26.66	4.44	7.43
December	96	20	W	69	56.64	8.50	3.54	42.32	7.54	5.35
December	97	50	W	71	10.26	7.96	6.72	16.63	6.06	5.02

[1]Relative humidity.
[2]Average wind speed in feet/minute.
[3]Wind direction.
[4]Temperature (°F).
[5]Aerobic plate count inside plant.
[6]Coliforms inside plant.
[7]Yeast and molds inside plant.
[8]Outside data around oyster shell piles.
[9]NT = Not tested.

Statistics

Microbial data from the various locations around the piles were averaged and the relationship correlated between these counts and the microbial loads found in the plants. Stepwise regression analysis was performed on the total aerobic counts, coliforms, and yeast and molds inside the plant using the following independent variables: Relative humidity, average wind speed, temperature, wind direction, and outside total aerobic counts, coliforms, and yeast and molds. Additional analyses were performed after stepwise regression to determine significance.

Results and Discussion

Oyster Waste Data

The total aerobic counts (Table 1) obtained within the oyster plant had the highest correlation with the interaction of aerobic counts around the shell pile and wind speed ($r = 0.86$). In other words, as the aerobic counts in the air immediately around the shell pile increased and as the wind speed increased, a significant correlation was shown with increased aerobic counts of air within the plant. Other interactions with aerobic counts around the pile such as temperature, wind direction, and relative humidity, did not correlate with increased microbial counts of the air within the plant.

The interaction of total coliforms and wind direction around the pile correlated very highly with the total coliforms enumerated in the plant ($r = 0.91$). As would be expected, the correlation was most significant when the shell pile was directly between the plant and the prevailing wind direction.

Yeast and molds levels in the air inside the plant demonstrated its highest correlation with the interaction of yeast and molds around the pile and relative humidity ($r = 0.73$). Interestingly, the lower the outside relative humidity was, the higher the levels of yeast and molds were.

Crab Waste Data

Analysis of the data generated from the crab waste bins produced no significant correlations. Table 2 shows the data from around the waste bin and inside the plant.

Discussion

When this project was developed, we thought that the waste piles could potentially be a significant source of airborne bacterial contamination. However, results indicate that the waste may be no more a significant source than are plant workers. Heldman (1967) reported that the bacterial contributions from food-plant workers ranged from 20 to 70 bacteria per minute. Results from around the oyster shell pile suggests APC ranged from 6.03 to 47.23 organisms/foot^3, coliforms ranged from 0.13 to 5.04 organisms/foot^3, and yeast and molds ranged from 0.46 to 13.31 organisms/foot^3. Ranges from the crab waste bin for APC, coliforms, and yeast and molds were: 4.30-80.54, undetected-16.34, and 0.20-23.51, respectively. Certainly the numbers of organisms enumerated from around the waste areas do not appear to be high, and, as suggested, plant workers may in fact be a more significant source of airborne contamination.

Organisms enumerated from the air within the plants were not as high as anticipated. Ranges per cubic foot of air in the oyster plant for APC's, coliforms, and yeast and molds were 4.25-310.10, 0.17-18.23, and 0.35-15.04, respectively. In the crab plant these ranges were APC's 1.06-0.09, coliforms undetected-16.99, and yeast and molds undetected-14.16. Furthermore, these counts seemed very reasonable, especially when compared with counts reported by Zottola et al. (1970) for a turkey processing plant of total bacteria 10,000/10L (28,300/foot^3) and 10/10L (28/foot^3) for coliforms. Beaucourt et al. (1977) reported an average total count of 4/10L (11.32/foot^3) in a modern meat processing plant.

While the numbers of organisms asso-

Table 2.—Meteorological conditions and number of organisms enumerated around crab waste bin and inside crab processing plant.

Year and month	RH[1]	Avg. wind speed[2]	WD[3]	Temp.[4]	Organisms/foot[3] of air					
					APC-I[5]	COL-I[6]	YM-I[7]	APC[8]	COL[8]	YM[8]
1983										
January	100	450	N	42	9.73	0	0	12.62	0	0.53
January	80	50	S	56	1.06	0	2.12	4.30	0.05	1.56
February	91	120	S	60	14.87	0	0	11.38	0.59	2.24
February	85	150	N	49	44.07	0	0.71	5.57	0	0.53
March	61	70	SE	70	63.53	2.12	0.35	6.60	0.50	0.20
1982										
April	92	300	N	54	ND[9]	16.99	7.78	12.56	0.41	0.97
May	81	1500	N	82	21.22	0.88	3.71	21.07	0.35	5.33
May	67	30	S	76	13.23	0.35	0.70	27.95	3.44	7.01
June	67	140	SW	76	28.29	1.94	2.12	33.02	1.73	16.10
June	82	75	S	85	13.10	1.23	0.70	15.78	0.35	3.92
July	71	100	S	91	17.52	2.83	0.17	28.61	1.88	1.44
July	65	125	SE	91	40.35	1.41	0.88	24.95	1.12	5.60
July	56	150	S	89	61.06	4.53	0.70	13.92	0.91	3.23
July	65	100	N	81	12.03	0.53	1.41	80.54	16.34	8.93
July	66	175	S	89	31.81	0.17	3.01	22.82	1.56	11.56
August	63	150	NE	83	18.41	0.88	5.13	52.92	7.01	15.24
August	76	100	S	86	52.00	0.17	2.47	35.43	1.35	4.25
August	81	80	SW	71	16.95	0.88	1.76	14.76	1.41	4.71
August	55	150	N	90	50.44	7.08	7.43	55.48	3.55	23.51
September	72	200	N	80	27.79	1.77	5.48	23.54	8.34	11.03
September	73	275	N	72	70.09	1.06	0.88	8.96	1.47	2.50
September	71	75	S	78	38.76	9.38	3.18	19.05	1.35	5.45
October	75	70	SE	75	17.15	4.24	2.47	20.91	1.35	5.36
October	65	120	SW	75	14.16	0.53	5.31	25.31	5.42	4.48
November	67	170	S	70	23.19	2.47	7.43	21.32	5.31	7.19
November	90	150	N	74	42.12	7.43	14.16	43.18	4.21	8.25

[1]Relative humidity.
[2]Average wind speed in feet/minute.
[3]Wind direction.
[4]Temperature (°F).
[5]Aerobic plate count inside plant.
[6]Coliforms inside plant.
[7]Yeast and molds inside plant.
[8]Outside data around crab waste bin.
[9]ND = No data.

ciated with waste piles are not large, nonetheless, it is interesting to note the correlations that were observed between conditions outside the plant and bacteria numbers and types found inside the plant. First, it is not too surprising that significant correlations were not associated with the crab waste bins inasmuch as this waste is emptied from the bins at least once a day and twice daily during the summer. Furthermore, due to problems encountered with flies, it is a common practice to throw lime into the bins when emptied, especially during the summer months. The combination of frequent removal and high pH are no doubt important factors mitigating potential airborne contamination which could result from the waste.

Oyster shells, however, remain in piles around the plants for days and often weeks. Pieces of oyster meats are frequently found adhering to the shells, thus serving as a nutrient source for microbial proliferation. The data indicate that the interaction of aerobic plate counts around the pile and wind speed were significantly correlated with increased counts within the plants. Although this is precisely the type of interaction which was hypothesized at the beginning of the study, the numbers involved are low.

The high correlation of total coliforms around the oyster shell pile and wind direction, with the total coliforms enumerated in the plant is of interest. Coliforms and specific organisms within the coliform group are often used as indicators of sanitary quality. While the number of coliform organisms enumerated were low, the number of certain coliform organisms, such as *E. coli*, allowed on food products are also low. Although the coliforms enumerated in this study were in all likelihood of environmental origin, given the problems encountered by the oyster industry during the past few years, even these sources can cause regulatory problems (Hackney et al.[3]).

The relationship of yeast and molds to relative humidity demonstrated some degree of correlation (r = 0.73). The lower the humidity was, the more yeast and mold organisms were enumerated in the air. Although it is well documented that these organisms have a greater tolerance to dry conditions, the significance of this to the present finding is uncertain.

[3]Hackney, C., D. Sbaih, L. Reily, M. Kilgen, and M. Cole. 1983. Non-*E. coli* fecal coliforms in oysters. Paper presented at the Interstate Seafood Seminar, Ocean City, Md., 1-3 Nov.

Summary

Although, during this study, the contribution of airborne contamination from waste piles was demonstrated to be comparatively small, the potential for contamination exists. Therefore, it would be prudent to take precautions to limit airborne contamination from waste piles, or other potential sources. Such precautions could include: 1) Locate waste piles away from the immediate vicinity of doors and windows, 2) ventilation fans and air conditioners should not be sited near waste piles, and 3) empty waste bins as often as possible.

Acknowledgment

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